

Food Intake and Overweight in School-Aged Children in Germany: Results of the GINIplus and LISAplus Studies

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Key Words

Food intake · Overweight · Child · BMI z-score · Energy partition model · Epidemiology

Abstract

Objective: To investigate the cross-sectional association between food intake and overweight in children. **Methods:** Height and weight were measured in 2,565 school-aged children. Intakes of 11 food groups were categorized (low, medium and high) using specific tertile cutoffs. Multivariate energy partition models were applied. Adjustment included energy intake from other food groups, city, family income, parental education and 'screen' time. Possible underreporters were identified and used in sensitivity analyses. **Results:** Compared to low intake, high intakes of meat, fish, beverages and bakery products were associated with greater BMI z-scores [β (95% CI) = 0.32 (0.21, 0.42), 0.13 (0.03, 0.24), 0.23 (0.11, 0.35) and 0.10 (–0.01, 0.20)] and increased risk of being overweight [odds ratio (OR) (95% CI) = 2.08 (1.58, 2.73), 1.39

(1.08, 1.80), 1.36 (1.01, 1.84) and 1.62 (1.24, 2.11)]. Conversely, medium and high intakes of confectionery were associated with smaller BMI z-scores [β = –0.18 (–0.28, –0.07) and –0.22 (–0.33, –0.12)] and decreased risk of being overweight [OR = 0.64 (0.50, 0.83) and 0.53 (0.40, 0.68)]. These associations were robust to sensitivity analyses. **Conclusions:** Intakes of meat, fish, beverages and bakery products correlate with body weight status.

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Introduction

Obesity is a major public health concern [1, 2]. Childhood obesity often persists into adulthood and can substantially decrease quality of life [3], increase the risk of metabolic syndrome and adult morbidities [4, 5], and be a heavy financial burden on the public health system [6].

Obesity is mainly a consequence of an unbalanced energy status [7]. Hence, the influence of diet (intake of in-

dividual nutrients and certain food items, dietary patterns and habits) and energy intake have been considered in many studies on the etiology of obesity [8–11]. However, the findings are difficult to reconcile [12, 13]. Several different types of models (i.e. standard multivariate model, residual nutrient model, energy partition model, multivariate nutrient density model) are commonly used in epidemiological studies, which are adjusted for total energy intake (TEI) [14]. The results of these models can and have been interpreted using different perspectives. One important difference between energy partition models and other types of models mentioned above is that the coefficient calculated from this former type of model represents both energy and nonenergy associations with the nutrient. The coefficient obtained from other model types leads to isocaloric substitution interpretations [14, 15]. Isocaloric interpretations are problematic when TEI is associated with the outcome under study [14], which may be one potential explanation for the conflicting results of previous studies. Another possibility could be the misreporting of energy intake in dietary assessment [16]. Moreover, selective reporting possibly exists. Results from the ALSPAC study revealed that underreporters had lower records of fat-/sugar-containing foods such as biscuits, cakes, chocolates and sweets [17]. Additionally, factors including food habits and portion size estimation, as well as ethnicity and cultural differences, may also influence the accuracy of food intake data [16].

The association between food intake with BMI z-scores and being overweight during childhood remains controversial [18]. In the current study, we used data from two German birth cohorts to examine cross-sectionally whether the intake levels of specific food groups are associated with being overweight or obese at the age of 10 years, after adjusting for energy from all other food groups and other potential confounding factors.

Materials and Methods

Study Population

Data from two ongoing German birth cohort studies were used in the current analysis. GINIplus (German Infant Nutritional Intervention Plus Environmental and Genetic Influences on Allergy Development) is an ongoing birth cohort study initiated to prospectively investigate the influence of a nutritional intervention during infancy, as well as air pollution and genetics on allergy development. GINIplus participants (n = 5,991 newborns) were recruited from obstetric clinics in Munich and Wesel between September 1995 and July 1998. Details of the study design are described elsewhere [19]. During the first 4 months, a total of 2,252 newborns with atopic heredity participated in a hydrolyzed pro-

tein infant formula intervention study [20]. This randomized controlled study showed that the BMIs of children at 1 year were marginally different among the formula groups, but not at 6 and 10 years of age [21].

LISApplus (Influences of Lifestyle-Related Factors on the Immune System and the Development of Allergies in Childhood Plus Air Pollution and Genetics) is an ongoing birth cohort examining the impact of lifestyle-related factors, air pollution and genetics on immune system and allergy development in childhood. In total, 3,097 neonates were recruited from 14 obstetrical clinics in Munich, Leipzig, Wesel and Bad Honnef between November 1997 and January 1999. A detailed description of the study's screening and recruitment has been described previously [22].

During the 10-year follow-up, information on food intake was collected from 3,437 participants (2,194 from GINIplus, 1,243 from LISApplus) by means of a validated semiquantitative food frequency questionnaire (FFQ). Height and weight were measured for 3,116 participants (1,918 from GINIplus, 1,198 from LISApplus) during the 10-year physical examinations. In the current study, 2,565 children (1,308 males, 1,257 females) from GINIplus (n = 1,596) and LISApplus (n = 969) with complete data on FFQ and BMI are included (fig. 1).

Approval by the respective local ethics committees (Bavarian General Medical Council, University of Leipzig, Medical Council of North Rhine-Westphalia) and written consent from all participating families were obtained for both studies.

Definition of Outcomes: BMI z-Scores and Overweight

Weight and height were measured by physicians during the 10-year physical examinations. BMI values were calculated and transformed to age- and sex-specific BMI z-scores using WHO macros [23]. Children were defined as being overweight or obese using the BMI z-score standard deviation (SD), according to WHO guidelines [24]. Children with BMI z-scores greater than one SD (BMI z-score > +1 SD) were defined as overweight. Children of normal weight (BMI z-score ≤ +1 SD) were used as the reference group in all models. As the number of obese (BMI z-score > +2 SD) children was small (n = 116), we included these children with the overweight group.

Definition of Predictors: Eleven Food Groups

The details and effectiveness of the FFQ have been published elsewhere [25]. Briefly, information on food intake frequencies and portion sizes of 82 food items were collected using parent-completed questionnaires. Seventy-nine food items were grouped into 11 food groups according to the Codex General Standard for Food Additives' food category system [26]. We excluded three food items: nut nougat cream, water and syrup. Nut nougat cream has a complex composition and could not be adequately classified into one food group. Syrup intake was very low in the current study. Water intake was excluded as its consumption does not yield energy. However, we used water intake as an additional adjustment variable when assessing the association between beverage intake and the outcomes, as beverage intake is reported to be associated with water intake [27]. Information on the intake of sweeteners, salts, spices, soups, sauces and foodstuffs intended for particular nutritional uses were not available in the current study.

For each of the 11 food groups, the intake for each child in grams per day was calculated. Because the distributions of the food

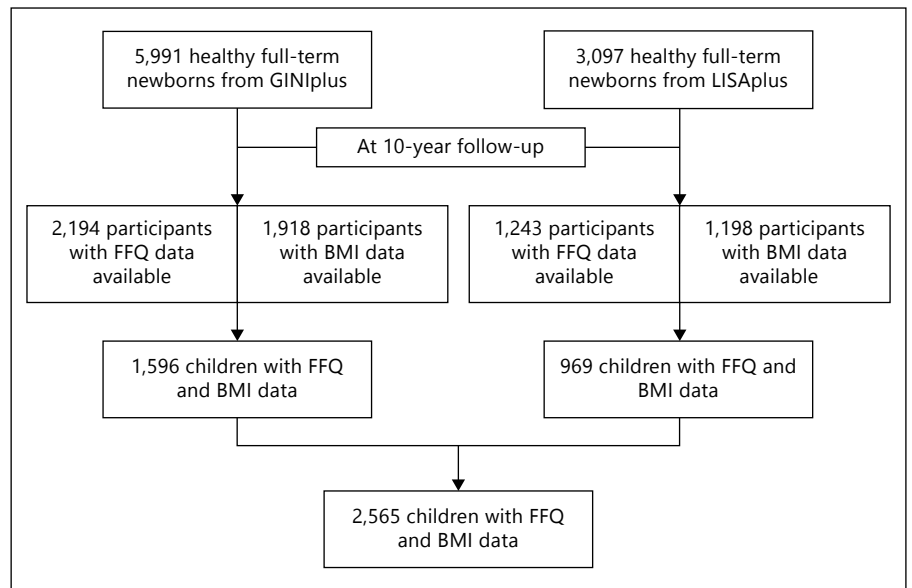


Fig. 1. Flow chart of the study population.

intakes were positively skewed, we categorized these values into three levels (low, medium, high) using group- and sex-specific tertile cutoffs.

Potential Confounding Factors

We included several potential confounding factors that confound the association between food intake and the outcomes of interest. The set of covariates examined were city of residence (Munich, Wessel, Bad Honnef, Leipzig), parental education level, family income and 'screen time'. Parental education levels were defined according to the highest number of years either parent attended school (low <10, medium = 10 and high >10). Family income was defined into three categories according to the city-specific quartiles of monthly average income (low <25%, medium 25–75% and high >75%). We used time spent in front of a screen (including TV, video and computer viewing), referred to as 'screen time', as a sedentary behavior covariate, as sedentary behavior has been associated with greater increases in BMI between the ages of 9 and 15 years [28]. This variable was collapsed into two categories: low screen time included children who spent <1 h per day in summer and <2 h per day in winter in front of a screen, and high screen time included children who spent ≥1 h per day in summer and ≥2 h per day in winter in front of a screen. In addition, there were 15 children who spent <1 h per day in summer and ≥2 h per day in winter in front of a screen. These children were placed in the high screen time category.

We additionally defined a variable 'underreporter versus plausible energy intake reporter' based on a ratio of TEI to basal metabolic rate (BMR). BMR is estimated using height, weight and age according to Mifflin et al. [29]. Because approximately 70% of total energy expenditure is used for basal life processes [30], we defined an underreporter as a child with $0.7 \times \text{TEI} < \text{BMR}$. A plausible energy intake reporter was defined as a child with $0.7 \times \text{TEI} \geq \text{BMR}$. As the estimation of BMR and the cutoff used to differentiate underreporters and plausible energy intake reporters may not be entirely accurate [31], this variable was not included in the final models, but rather was used for descriptive and sensitivity analyses only.

Statistical Analysis

As preliminary analyses suggested no differences in the associations between food intakes and BMI z-scores by sex, data for males and females were pooled for all analyses. For each of the 11 food groups, unadjusted and multivariate energy partition models [15] were used to examine the associations between each food group intake (in grams per day) with BMI z-scores and being overweight. Low intake levels were used as the reference group in all models. According to the definition of the partition model [14], we calculated energy intake from the food group itself and energy intake from all other food groups. Instead of TEI, energy intake from all other food groups was included as a covariate in the models. For each food group, there was a specific energy intake from all other food groups.

Differences between respondents and nonrespondents as well as overweight and normal weight subjects were tested using Pearson's χ^2 test for categorical variables and Student's t test for continuous variables. Study characteristics are described using means and SD or n (%). Model results are presented as linear regression coefficients (β) for BMI z-scores and odds ratios (OR) for being overweight, with corresponding 95% CI [β (95% CI) or OR (95% CI), respectively]. All analyses were performed using the statistical software package R, version 2.14.1 [32].

Additional sensitivity analyses were performed. To examine whether the formula intervention in the GINIplus study attenuated our results, sensitivity analyses in which the models were additionally adjusted for formula type were conducted. To study the potentially existing underreporting issue in the present study, analyses were stratified by 'underreporter versus plausible energy intake reporter'. In addition, sensitivity analyses adjusting for this variable in the pooled models were performed. To compare the effect size of the associations between food items that had similar dietary content with BMI z-scores and being overweight, we performed analyses in several pairs: red meat (i.e. pork, beef, sausage) versus white meat (i.e. chicken), freshwater fish versus saltwater fish, fish sticks versus other fish subgroups, vegetables versus fruits

Table 1. Characteristics of study population at 10 years of age with available BMI and FFQ data (n = 2,565)

	Mean (SD) or % (n/n)
Female	49.0 (1,257/2,565)
Study	
GINIplus	62.2 (1,596/2,565)
LISAplus	37.8 (969/2,565)
City of residence	
Munich	56.1 (1,438/2,565)
Leipzig	9.3 (238/2,565)
Bad Honnef	4.9 (125/2,565)
Wesel	29.8 (764/2,565)
Family income ^a	
Low	21.3 (499/2,346)
Medium	48.0 (1,126/2,346)
High	30.7 (721/2,346)
Parental education ^b	
Low	4.7 (120/2,555)
Medium	26.0 (665/2,555)
High	69.3 (1,770/2,555)
High screen time ^c	31.4 (796/2,532)
Age at 10-year physical examination, months	122.5 (2.7)
BMI, kg/m ²	17.3 (2.4)
BMI z-score ^d	0.16 (1.05)
BMI z-score category ^e	
Normal weight	80.3 (2,059/2,565)
Overweight	19.7 (506/2,565)
TEI, kcal	2,082 (606)

^a Defined according to quartiles of monthly average income: low <25%, medium 25–75% and high >75%. ^b Categorized according to the highest number of years either parent attended school: low <10 years, medium = 10 years and high >10 years. ^c Low for <1 h per day in summer and <2 h per day in winter; high for ≥1 h per day in summer and ≥2 h per day in winter. ^d Calculated using WHO macros [23]. ^e According to WHO guidelines [24].

and chocolate/chocolate bars versus soft sweets. We additionally investigated associations between BMI z-scores and the individual food items which had been combined into the bakery products and beverages food groups.

Results

Characteristics of the study population at 10 years of age are shown in table 1. Female participants comprised 49.0% of the sample. The mean BMI z-score was 0.16, which suggests that the majority of the study population had a larger BMI than the reference population. The SD was approximately 1.00, as expected [33]. The prevalence of overweight was 19.7%. The average TEI was 2,082 ±

606 kcal. The characteristics of children included in the current analyses and those from the original birth cohorts who were not included are significantly different in the following three aspects: weight of children at age 10 years, family income at age 10 years and parental education level. The children who were excluded from the present study were more likely to be overweight at age 10 years (25.4%), from low-income families (25.2%) and to have parents with low education level (13.0%) compared to those included in this analysis (19.7, 21.3 and 4.7%, respectively; data not shown).

The proportion of underreporters among overweight and normal weight participants is shown in table 2. Compared to participants of normal weight, there was a significantly higher proportion of underreporters among overweight participants for both males and females (32.6 vs. 19.2% and 27.6 vs. 17.1%, respectively; $p < 0.001$). Details of which food items were grouped into which food groups are shown in table 3. The food intake of each food group in grams per day as well as percent energy consumed per day is shown in table 4.

The adjusted coefficients for the association between food group intakes and BMI z-scores at 10 years of age are shown in figure 2. Compared to children with a low intake of meat and meat products, children with medium and high intakes had greater BMI z-scores [$\beta = 0.10$ (0.00, 0.20) and 0.32 (0.21, 0.42), respectively]. Children with high fish and beverage intakes had greater BMI z-scores than those with low fish and beverage intakes [$\beta = 0.13$ (0.03, 0.24) and 0.23 (0.11, 0.35), respectively]. Compared to children with a low intake of confectionery, children with medium and high confectionery intakes had smaller BMI z-scores [$\beta = -0.18$ (-0.28, -0.07) and -0.22 (-0.33, -0.12), respectively]. No significant associations were found for the rest food groups.

Adjusted ORs for the association between food intake groups and being overweight at 10 years of age are shown in figure 3. Compared to low-intake groups, those with high intakes of meat, bakery products, fish and beverages had a higher risk of being overweight [OR = 2.08 (1.58, 2.73), 1.62 (1.24, 2.11), 1.39 (1.08, 1.80) and 1.36 (1.01, 1.84), respectively]. Furthermore, those with medium and high intakes of confectionery were at a decreased risk of being overweight [OR = 0.64 (0.50, 0.83) and 0.53 (0.40, 0.68), respectively]. No significant associations were found for the other food groups. Additional adjustment for formula type did not substantially change our results (data not shown).

Adjusting additionally for ‘underreporter versus plausible energy intake reporter’ attenuated the effect

Table 2. Underreporters^a by weight status in the study population, stratified by sex

Weight status ^b	Male		Female		Total	
	underreporter	plausible energy intake reporter	underreporter	plausible energy intake reporter	underreporter	plausible energy intake reporter
Normal weight, n (%)	200 (19.2)	841 (80.8)	174 (17.1)	844 (82.9)	374 (18.2)	1,685 (81.8)
Overweight ^c , n (%)	87 (32.6)	180 (67.4)	66 (27.6)	173 (72.4)	153 (30.2)	353 (69.8)

^a Underreporter: BMR <70% TEI; plausible energy intake reporter: BMR ≥70% TEI. ^b Normal weight: BMI z-score < +1 SD; overweight: BMI z-score ≥ +1 SD. ^c Significant difference between overweight and nonoverweight groups, tested by Pearson's χ^2 test, $p < 0.001$.

Table 3. Definition of food groups^a

Food groups	Food items included
Dairy and dairy products	cheeses, milk and yogurts, cream, fresh cream
Fats and oils	butter and margarines, oils
Fruits and vegetables	cooked potatoes, nuts, pumpkin, pine seeds, sunflower seeds, carrots, peppers, spinach, chard, cabbage, lettuce, apples, pears, citrus fruits, berries
Confectionery	chocolate, chocolate bars, soft sweets
Cereal	muesli, cereals, corn flakes, crispy, rice, pasta, noodles
Bakery products	bread, toast, multigrain bread, whole-wheat bread, white rolls, pretzels, croissants, chocolate rolls, cakes, pastries, cookies, biscuits
Meat and meat products	pork, beef, veal, poultry, organ meats, sausage, salami
Fish and fish products	freshwater fish, saltwater fish, herring, fish sticks, canned fish
Eggs and egg products	egg, scrambled egg, fried egg, semolina, pudding, rice pudding
Beverages	fruit juices, fruit nectars, vegetable juices, diluted juices, sparkling drinks, lemonade, cola, ice tea, sport drinks, energy drinks, tea
Ready-to-eat savories	crisps, chips, croquettes, pizza

^a Defined according to the Codex General Standard for Food Additives food category system [26].

Table 4. Distribution of food intake in the study population (g/day)

Food groups ^a	Median	33rd percentile		66th percentile		%En ^b
		male	female	male	female	
Dairy and dairy products	315	259	217	477	378	14.4
Fats and oils	14	11	10	19	18	4.0
Fruits and vegetables	279	214	235	325	348	7.4
Confectionery	16	11	10	25	20	3.0
Cereal	80	66	60	108	95	14.3
Bakery products	141	119	112	173	161	18.4
Meat and meat products	97	84	68	133	109	12.0
Fish and fish products	16	12	10	24	21	1.2
Eggs and egg products	18	13	12	26	22	1.4
Beverages	573	399	339	852	728	8.0
Ready-to-eat savories	41	35	29	53	46	4.9

^a Defined according to the Codex General Standard for Food Additives food category system [26]. ^b Median percent energy consumed per day.

Fig. 2. Adjusted coefficients for the association between food group intake tertiles and BMI z-scores. Models are adjusted for energy intake from other food groups, city of residence, family income, parental education and screen time. ^a The association between beverage intake and BMI z-scores was additionally adjusted for water intake.

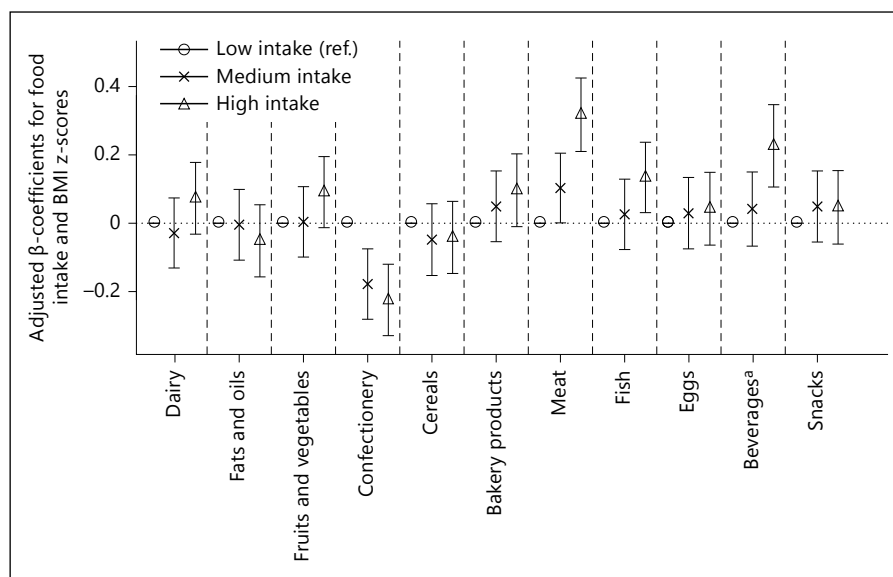
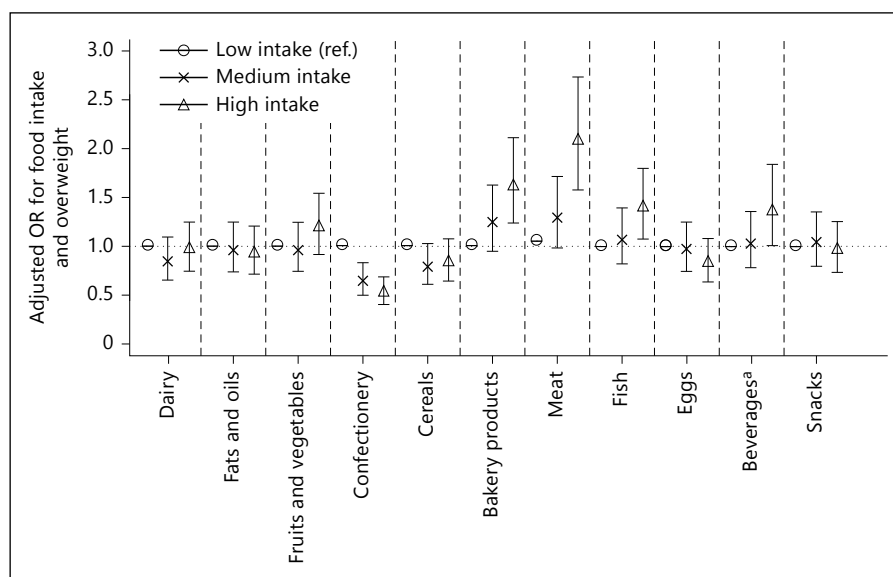


Fig. 3. Adjusted OR for the association between food group intake tertiles and being overweight. Models are adjusted for energy intake from other food groups, city of residence, family income, parental education and screen time. ^a The association between beverage intake and being overweight was additionally adjusted for water intake.



size, but the association between BMI z-scores and confectionery intake was still significant [β : -0.18 (-0.28, -0.07) vs. -0.12 (-0.23, -0.02) and -0.22 (-0.33, -0.12) vs. -0.13 (-0.24, -0.03) for medium and high intake of confectionery before and after adjustment, respectively]. The association between being overweight and confectionery intake also remained significant with attenuated effect size [OR: 0.64 (0.50, 0.83) vs. 0.71 (0.55, 0.93) and 0.53 (0.40, 0.68) vs. 0.63 (0.48, 0.82) for medium and high intake of confectionery before and after adjustment, respectively]. Moreover, effect estimates for un-

derreporters were not notably different than those for plausible energy intake reporters. Detailed numbers are provided in online supplementary table 1 (www.karger.com/doi/10.1159/000362694).

Analyses stratified by red meat and white meat yielded significantly positive associations with BMI z-scores [β for medium intake: 0.07 (-0.03, 0.18) vs. 0.27 (0.11, 0.42) and β for high intake: 0.20 (0.09, 0.31) vs. 0.22 (0.13, 0.31) for red meat and white meat, respectively] and being overweight [OR for medium intake: 1.16 (0.89, 1.52) vs. 1.77 (1.22, 2.58) and OR for high intake: 1.57 (1.20, 2.06) vs.

1.64 (1.31, 2.05) for intake of red meat and white meat, respectively] for both subgroups. Also, the analyses stratified by freshwater fish and saltwater fish showed similar results [OR for medium intake: 1.22 (1.01, 1.65) vs. 1.27 (1.00, 1.66) and OR for high intake: 1.28 (1.02, 1.68) vs. 1.32 (1.02, 1.72) for freshwater fish and saltwater fish, respectively]. High intake of fish subgroups that exclude fish sticks was significantly associated with being overweight [OR: 1.47 (1.15, 1.87)], but this was not the case for high fish stick intake [0.94 (0.75, 1.19)]. Analyses stratified by fruit and vegetables yielded a marginally significant association between high intake of vegetable and increased BMI z-score [β : 0.11 (0.01, 0.22)]. However, high vegetable intake was not associated with being overweight [OR: 1.26 (0.97, 1.64)]. Analyses stratified by chocolate/chocolate bars and soft sweets revealed that chocolate/chocolate bars had smaller estimate coefficients than soft sweets [medium intake: 0.67 (0.52, 0.87) vs. 0.94 (0.73, 1.22) and high intake: 0.68 (0.53, 0.89) vs. 0.71 (0.55, 0.92), respectively]. The estimate coefficients only slightly differed among the different bakery food items, and were all significant (data not shown). The effect estimates and significance in sugar-sweetened beverages (e.g. cola, nectars, lemonade, energy drinks, etc.) were greater compared to that in juices (e.g. fruit juices, diluted juices, vegetable juices, etc.); the associations between BMI z-scores and beverages were all significant (data not shown).

Discussion

In the present study, we observed significant positive cross-sectional associations between high intakes of meat, fish, bakery products and beverages with BMI z-scores and with being overweight at 10 years of age. Moreover, confectionery intake was negatively associated with BMI z-scores and being overweight. Additional model adjustments for energy reporting status and other sensitivity analyses did not substantially change our results.

Meat and Fish Intake and BMI

Although data from the cross-sectional KiGGS study ($n = 13,450$) revealed a similar association between high intake of meat with overweight and obesity in 3- to 17-year-old children [34], our findings should be interpreted with caution as our study is cross-sectional. Animal protein may play a role in the associations, as meat and fish are rich in it. Results from the DONALD study showed significantly positive associations between animal protein intake during puberty and fat-free mass in

young adulthood [35], which is in line with evidence from randomized controlled trials in children [36, 37] and adults [38]. Thus, the association between BMI and intake of meat and fish may be a reflection of accumulating fat-free mass. The association between BMI z-scores and fat mass and fat-free mass is reported to vary according to the degree of body fatness (overall multiple R^2 ranged from 0.90 to 0.96) [39]. Among children with BMI z-scores $> +1$, BMI z-scores were more strongly associated with fat-free mass than fat mass. In contrast, among children with BMI z-scores $\leq +1$, BMI z-scores were more strongly associated with fat mass than fat-free mass [39].

Several studies have reported positive associations between protein intake during early life (<1 year) and obesity in childhood [40–42]. The hypothesis behind this observation is that higher protein intake during early life is associated with faster weight gain [40]. However, the protein intake of rapid growers at 2 years of age did not influence the change in BMI z-scores between 2 and 5 years of age in the DONALD study [43]. Our study population (of 10-year-old children) is nearing puberty, a developmental stage during which fast weight gain is possible. Whether protein intake in puberty contributes to weight gain remains unclear, could not be addressed in this analysis and needs to be explored in future studies.

Meat consumption has been identified as a lifestyle indicator in several adult studies [44, 45]. Compared to vegetarians, meat consumers had lower education levels, lower socioeconomic statuses and lower household incomes. These factors may have an impact on the onset of obesity [46, 47]. Overall, the associations between meat intake with BMI z-scores and being overweight were robust, regardless of which models were used or which confounders were considered. These consistent associations highlight the need for future prevention and intervention against overweight and obesity among children.

Confectionery Intake and BMI

We observed negative associations between confectionery intake and BMI z-scores. Associations between confectionery intake and BMI z-scores are conflicting [48, 49]. We believe there are two possible explanations for our results. First, the seemingly protective effect of confectionery might be attributable to reverse causation. An energy-dense, high-fat, low-fiber dietary pattern has been identified as a correlate of increased adiposity during childhood and adolescent [50]. Parents of overweight or obese children, or the children themselves, may have consciously reduced or limited their confectionery intake to lose weight. This artifact would have caused the results

to indicate that children of normal weight consume more chocolate and candies than overweight children. Moreover, potential reporting bias may be possible as underreporters usually have higher weight statuses [16, 50, 51]. It is also possible that children and parents underreported the intake of 'unhealthy food' [17]. However, adjusting for underreporters did attenuate the effect size, but the association was still significant. Second, as sugars can stimulate satiety in the short term (2 h) [52], intake of confectionery could have reduced subsequent food intake, which could lead to lower BMI. In the current study, the overall energy contribution of confectionery was low (median percent energy consumed per day: 3.0%), which does not support a major causal role of confectionery for high BMI.

O'Neil et al. [53] examined the effect of candy consumption on obesity using data from the NHANES study in 11,181 participants (age ranged from 2 to 18 years). Candy consumers (approx. 25% of the total population) had lower ORs for being overweight (0.78, 95% CI: 0.68–0.90) and obese (0.74, 95% CI: 0.66–0.82) after adjusting for sex, ethnicity, age and energy intake. Another study in 1,139 Saudi Arabian males aged 10–14 years reported that children who consumed sweets and candy one or more times per day were at a higher risk of being overweight (OR: 1.7, 95% CI: 1.3–2.3). However, this OR was not adjusted for potential covariates [54].

Intakes of Bakery Products and Beverages and BMI

In the current study, 11 kinds of bread or cakes were combined into a bakery products group (e.g. whole-grain bread, refined bread, cream cake, etc.). The materials used in the production of these items likely differ (e.g. polyols, sugar alcohols, natural sweeteners, sucrose, etc.). Therefore, the associations between BMI z-scores and these food items were examined individually. However, the estimate coefficients of different bakery food items only slightly differed. In general, bakery products belong to medium-to-high glycemic index categories [55], which may help explain the associations between BMI and consumption of bakery products [56]. In addition, reverse causation and misreporting may exist in the association between bakery product intake and overweight, as bakery products are also energy-dense, high-fat, low-fiber food [17, 50]. Therefore, the true OR may be even larger than observed. However, to which extent these possibilities may affect the results must be interpreted cautiously. For example, with confectionery and bakery products, intake of confectionery is usually between meals, which is likely to be restricted (especially for overweight children); how-

ever, bakery products are always consumed during meals, and a child is unlikely to skip main meals even if he is overweight. Thus, the potential effect of reverse causation may be stronger for confectionery intake compared to bakery products. Future studies are needed to explore these possibilities in different food groups.

Previous studies suggest a possible link between intake of soft drinks with increased BMI and obesity [18, 57]. Beverage intake may contribute to a higher BMI by increasing TEI. This hypothesis is supported by several studies in children and adolescents [58, 59]. Greater effect estimates and significance in sugar-sweetened beverages in comparison to juices were observed in the current study. Both the higher levels of sugar in sugar-sweetened beverages and lower consumptions of juices could have contributed to this difference.

Strengths and Limitations

The current study has several strengths. Our analyses are based on two large population-based cohorts with measured anthropometric data. The food groups are defined according to the WHO food category system, which allows our results to be compared to future studies. Instead of providing isocaloric interpretations, the multivariate energy partition models allowed us to interpret our results while taking both energy and nonenergy effects of foods into account. Sensitivity analyses were nevertheless conducted using different models (i.e. multivariate standard model and multivariate density model; results not shown), and similar results were obtained.

Our study has some limitations. First, only cross-sectional data were available for this exploratory analysis. Thus, cause and effect associations cannot be drawn. Second, data on body composition and fat mass were not available. These data would have provided more information on weight status rather than only using BMI. However, it has been shown that the percentage of body fat and BMI have similar patterns over time [60]. Third, reporting bias may exist in our study as we used data collected from questionnaires. Differential, selective underreporting may have thus influenced our results, especially for overweight participants, as has been previously observed [16, 50, 51]. We did observe a higher proportion of underreporters in overweight participants for both males and females, although the definition of underreporters used in our study is not ideal. However, additional adjustment for the 'underreporter vs. plausible energy intake reporter' did not notably change our results. Still, the high proportion of potential underreporters (approx. 30%) calls for the use of caution in future studies.

Conclusion

Our results suggest that a high intake of meat, fish, beverages and bakery products is associated with increased body weight status. Particularly, meat intake may be an important correlate of being overweight. The influence of possible reverse causation on the association between food intake and being overweight needs to be explored in future studies.

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